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Mathematical Modelling for Prediction of Angular Distortion in MIG Welding of Stainless Steel 301

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Abstract: GMAW is one of the best suited techniques widely used in fabrication industry for joining applications. GMAW can be used in semi-automatic and fully automatic modes as per the requirements. Its portability, versatility, good quality welds and capability of all position welding makes it a preferred joining process in general job shop as well as mass production units. Given the popularity and wide applications of this process, it becomes necessary to understand and analyse the performance of the same under varying conditions of input parameters. One of the weld quality issues that concerns significantly to the fabricators is of the angular distortion resulting from most of the arc welding processes. Angular distortion occurs during welding as a result of non-uniform expansion and contraction of the weld and base metal during the weld thermal cycle. In angular distortion, the stress is transverse to the welding direction and is caused due to shrinkage caused near the fusion zone resulting in the change in the angle of the parts. As the weld cools, this weld pool shrinks and due to the plastic deformation, lifting the plate and causing angular distortion, which may result in the rejection of the weldment. Post weld resolution of angular distortion may not be practically feasible. Therefore, there is a need to establish a relation between the input welding parameters like wire feed rate, arc voltage and nozzle to plate distance etc. and the resulting angular distortion so that the amount of the same can be predicted beforehand with fairly good accuracy. The present work aims at carrying out an experimental study to develop a mathematical model for this purpose for stainless steel 301. Statistical technique of design of experiments has been used to carry out experiments in a structured manner and adequacy of the model is checked by ANOVA technique. The results are analysed graphically using response surface methodology.

Keywords: GMA Welding, Stainless Steel, Angular Distortion, Design of Experiments, Mathematical Model, ANOVA, Response Surface Methodology.

I. INTRODUCTION

Arc welding processes are widely used throughout the industries, amongst which GMAW is the most favoured. In GMAW a spool of continuously fed wire is used, which can used to join long pieces of metals without breakage or stopping in between. The consumable wire is fed through a welding gun at a constant rate to the weld. Whereas, an inert gas shields the weld to prevent it from atmospheric contamination. Since there was no flux used, there was very little chance of entrapment of slag which leads to good quality welds also eliminating the need for any post weld cleaning requirements. GMAW can be fully automated using programmable robots making it suitable for mass production.

GMA welding involves highly localised heating of joint edges to fuse the material, non-uniform stresses are set up in the component because of heating and cooling of the heated material which then leads to deformation, these deformations are unavoidable because of uneven expansion and contraction experienced by different layers across the thickness of the material being welded[1]. Every effort should be made to keep these distortions minimum as they not only spoil the aesthetics of the joint but also result in dimensional deviations causing misfits in the final assembly[2]. The most common is angular distortion in which the distortion is transverse to the welding direction and caused by shrinking near the fusion zone leading to change in the angle of the plates. Post weld treatment is required to eliminate the distortion so that the work piece is defect free[3]. Angular Distortion is depicted schematically in Fig 1.

Fig. 1 : Schematic Diagram of Angular Distortion

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Post weld treatments can be very expensive, time consuming and sometimes impractical. Often times an initial negative angle is provided to the plates so that there is no angular distortion in the plates after welding, though it is difficult to obtain a complete analytical solution for determining the initial angle to be provided to the plates that may be reliable over a wide range of processes, materials and process control parameters. A need was therefore felt to address this issue by developing a mathematical model that connects the angular distortion with the input welding parameters. To formulate various combinations of parameters, Design of experiments (DoE) technique has been used, which facilitates the carrying out of the experiments in a structured manner so as to deduce a logical conclusion. A mathematical model has been generated whose adequacy has been checked by ANOVA technique and the results are graphically analysed by response surface methodology (RSM).

A series of trial experiments and literature survey has revealed that angular distortion is directly influenced by the width and depth of the fusion zone relative to plate thickness, the type of joint, the weld pass sequence, the thermo mechanical material properties, welding input parameters such as torch angle, nozzle to plate distance, wire feed rate, welding speed and voltage. [4]

SS301 is an austenitic chromium-nickel stainless steel. It possesses high strength and exceptional corrosion resistance, also provides weight reduction which gives it the ability to be widely used in multiple applications.[5] It also provides high ductility when cold worked and hence can be moulded into the desired shape. It is used in aircraft structural parts, utensils, automotive trims among other various applications. The approximate chemical composition of this material is given in the table 1 below.

TABLE 1: Chemical composition of SS301[6]

C	Si	Mn	S	Ni	Cr	P	N
0.100	0.620	0.790	0.003	6.580	17.000	0.027	0.057

SS301 is an adjustment of SS304, where the chromium-nickel level is lowered, it enables immense tensile strength with lower loss of ductility as compared to SS304. Type 301 shows corrosion resistance comparable to 302 and 304 in most mild service condition, resistance to food service requirements and atmospheric corrosion is excellent. The optimal corrosion resistance is obtained in the cold worked than in the annealed condition.

The electrode used in the process is of austenitic stainless steel 308L. The electrode is consumable, solid core type. The wire used is of diameter 1.2 mm. Stainless steel 308L is a low carbon form of austenitic stainless steel 308 which is generally used as filler metal for grades 301, 304, 321 stainless steel etc. The alloy has a low carbon content which makes it suitable for applications where there is a risk of inter-granular corrosion [7]. Stainless steel 308L contains 0.03% carbon which is less than SS-308 (0.05%) which makes it fairly more weldable and ductile. The approximate chemical composition of the given material is given below in table 2.

Table 2 : The chemical composition of SS-308L is given below:[8]

C	Mn	Si	Cr	Ni	S	P	Mo	Cu
0.03	1-2.5	0.30-0.65	19.5-22	9-11	0.03max	0.03max	0.75max	0.75max

II. EXPERIMENTAL SETUP

The experimental setup consists of a welding power source of current ranging from 50A- 400A. it provides a 100% duty cycle at the maximum current. The power source has a constant voltage type characteristic. To achieve the appropriate results a mechanized carriage was used where the torch was attached to a radial rotating arm which could move up and down and could be adjusted at various angles. The speed of the carriage varies from 0-50 cm/min. The filler wire used is austenitic stainless steel 308L of 1.2mm diameter which was continuously fed through the wire feeder. The setup is shown in figure 2.

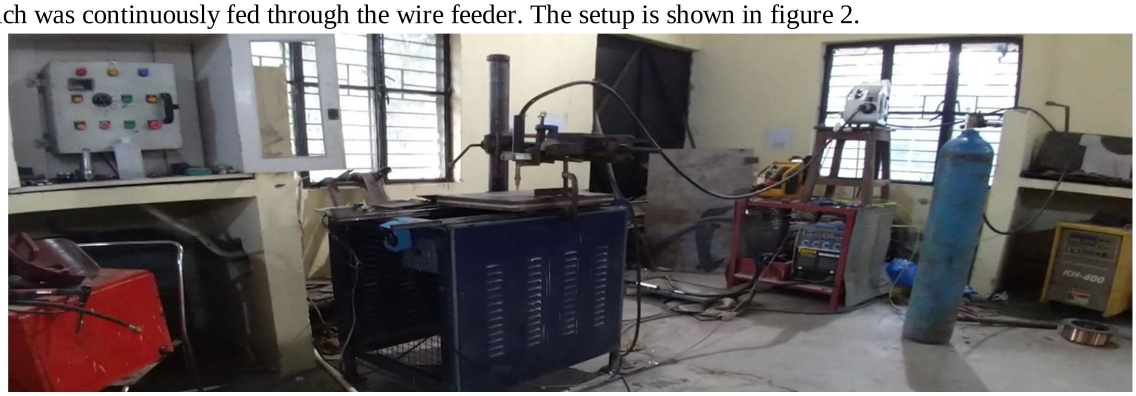

Fig 2 : Experimental Setup of GMAW

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III. PLAN OF INVESTIGATION

A. Selection of Important Input Parameters

From the extensive experimentation, five independently controllable input parameters have been selected which have significant effect on the angular distortion of the plates. These parameters are wire feed rate, welding speed, voltage, nozzle to plate distance and torch angle.

B. Determining the Working Limits of these Parameters

The estimation of the working limits of input parameters is concluded by a number of trial runs and visually observing the bead geometry for any visual defects. During a trial run only one input variable was varied while keeping the others some intermediate value. The range of each welding parameter is categorized into 5 different levels where +2 and -2 are the extremes, 0 is the central value and +1 and -1 are the intermediate values. The parameters and their values are shown in table 3.

Table 3: Working Limits of Welding Parameters

S.NO.	Input Parameters	Unit	Levels				
			-2	-1	0	+1	+2
1	Wire Feed Rate	m/min	0.3	0.6	0.9	1.2	1.5
2	Welding Speed	cm/min	30	35	40	45	50
3	Voltage	Volts	14	16	18	20	22
4	Nozzle to Plate Distance	Mm	10	12.5	15	17.5	20
5	Torch Angle	Degrees	70	80	90	100	110

C. Development of the Design Matrix

A design matrix is used to determine the relationship between the input parameters and the output parameter, it is constructed by DOE, given in table 4.

Table 4 : Design Matrix developed using DOE

Std	Run	WFR (m/min)	Voltage (v)	Speed (cm/min)	Angle (Degrees)	NPD (mm)	Angular Distortion (Degrees)
29	1	0	0	0	0	0	2.29
10	2	1	-1	-1	1	1	2.25
12	3	1	1	-1	1	-1	1.26
2	4	1	-1	-1	-1	-1	1.66
22	5	0	0	2	0	0	2.87
31	6	0	0	0	0	0	2.69
18	7	2	0	0	0	0	1.82
3	8	-1	1	-1	-1	-1	5.15
28	9	0	0	0	0	0	2.55
25	10	0	0	0	0	-2	3.43
23	11	0	0	0	-2	0	2.8
30	12	0	0	0	0	0	2.71
20	13	0	2	0	0	0	4.56
14	14	1	-1	1	1	-1	2.06
4	15	1	1	-1	-1	1	2.8
9	16	-1	-1	-1	1	-1	1.91
13	17	-1	-1	1	1	1	5.39
6	18	1	-1	1	-1	1	3.9
32	19	0	0	0	0	0	2.9

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1	20	-1	-1	-1	-1	1	0.87
24	21	0	0	0	2	0	2.33
19	22	0	-2	0	0	0	4.29
15	23	-1	1	1	1	-1	3.87
21	24	0	0	-2	0	0	1.01
8	25	1	1	1	-1	-1	5.47
11	26	-1	1	-1	1	1	2.86
26	27	0	0	0	0	2	3.12
7	28	-1	1	1	-1	1	3.2
27	29	0	0	0	0	0	2.48
5	30	-1	-1	1	-1	-1	2.91
16	31	1	1	1	1	1	2.54
17	32	-2	0	0	0	0	3.1

D. Conducting the Experiments as per the Design Matrix

The experiments were conducted as per the parameter combination suggested by the table 4. A total of 32 weld specimens were made in a random order just to eliminate systematic error, if any. The angular distortion of the weldments were measured as per the diagram shown in fig. 3. Each specimen was kept on a surface plate with one of its side pressed against the plate. The measuring probe of a Vernier height gauge was used to take first reading of this edge and recorded as R_1. The other edge of the specimen is now pressed such that the earlier edge is lifted by an amount of angular distortion. The probe of Vernier height gauge is again used to measure the height of the lifted edge and is recorded as R_2. Now, R_2-R_1 provides the perpendicular height from which angular distortion can be calculate by using Sin ϴ = R_2-R_1/plate width. Similar procedure is repeated for determining the angular distortion of the remaining specimen.

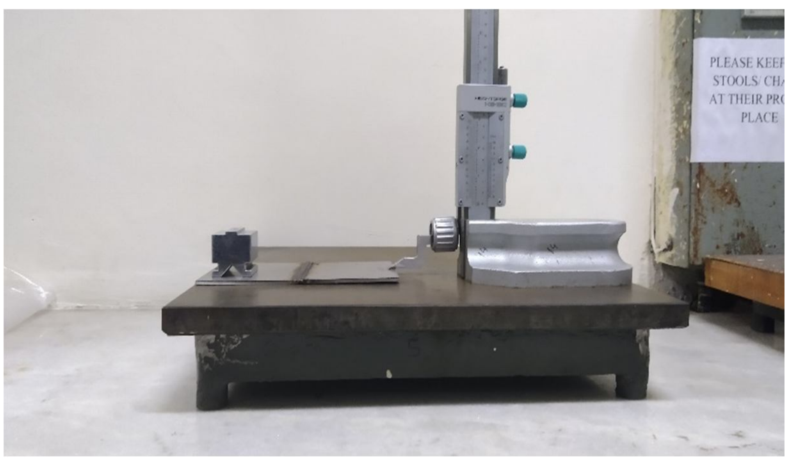

Fig 3 : Measurement of Angular Distortion

E. Development of the Mathematical Model

The second order polynomial equation developed by the software is given below. The equation represents the individual, interaction and quadratic effects of the parameters on the angular distortion.

Angular distortion (Y) = 2.60 - 0.28*A + 0.28*B + 0.59*C - 0.19*D - 0.04*E - 0.11*AB + 0.08*AC -0.47*AD + 0.16*AE - 0.28*BC - 0.52*BD - 0.51*BE + 0.03*CD + 0.12*E + 0.52*DE - 0.03*A^2 + 0.45*B^2 - 0.16*C^2 - 0.01*D^2 + 0.16*E^2

F. Checking the Adequacy of the Developed Model

Table 5 depicts the adequacy of the developed quadratic model calculated using the ANOVA analysis technique. It confirms that the given model is significant as the lack to fit is not significant. In table 6 the higher value R^2 confirms further accuracy of the developed model. Figure 4 shows the relationship between the actual and predicted values using a scatter diagram, where the points are closely sticking to the centre line without showing any pattern, further confirming the adequacy of the developed model.

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Table 5 : ANOVA Analysis for quadratic model.

	Source	Sum of Squares	Df	Mean Square	F-Value	p-value	
	MODEL	40.29	20	2.01	20.48	<0.0001	significant
	A-Wire Feed Rate	1.92	1	1.92	19.47	0.0010	
	B- Voltage	1.89	1	1.89	19.24	0.0011	
	C- Welding Speed	8.52	1	8.52	86.59	<0.0001	
	D- Torch Angle	0.9441	1	0.9441	9.59	0.0101	
	E- Nozzle to Plate Distance	0.0504	1	0.0504	0.5124	0.4890	
	AB	0.2025	1	0.2025	2.06	0.1792	
	AC	0.1260	1	0.1260	1.28	0.2818	
	AD	3.36	1	3.63	36.88	<0.0001	
	AE	0.4096	1	0.4096	4.16	0.0661	
	BC	1.30	1	1.30	13.21	0.0039	
	BD	4.37	1	4.37	44.39	<0.0001	
	BE	4.22	1	4.22	42.92	<0.0001	
	CD	0.0210	1	0.0210	0.2137	0.6529	
	CE	0.2304	1	0.2304	2.34	0.1542	
	DE	4.37	1	4.37	44.39	<0.0001	
	A^2	0.0412	1	0.0412	0.4192	0.5306	
	B^2	6.04	1	6.04	61.38	<0.0001	
	C^2	0.8203	1	0.8230	8.36	0.0147	
	D^2	0.0037	1	0.0037	0.0377	0.8495	
	E^2	0.8107	1	0.8107	8.24	0.0152	
	RESIDUAL	1.08	11	0.0984			
	Lack of Fit	0.8592	6	0.1432	3.21	0.1108	Not significant
	Pure Error	0.2231	5	0.0446			
	Cor Total	41.38	31				

Table 6 : Fitness of the developed Model

Std. Dev.	0.3137	R^2	0.9738
Mean	2.91	Adjusted R^2	0.9263
C.V. %	10.79	Predicted R^2	0.4354
		Adequate Precision	18.6287

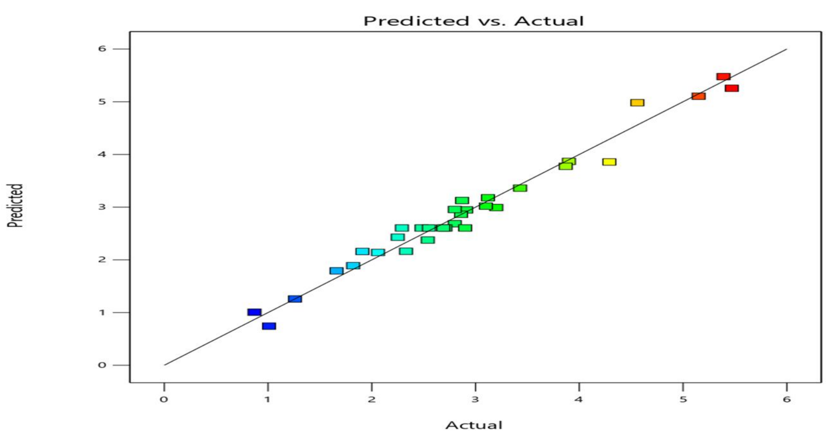

Fig 4 : Actual VS Predicted Scattering

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G. Analysis of Results and Discussions.

The graphical results obtained (fig. 5-7) are analysed in the following sections.

1) *Effect of Voltage and WFR on Angular Distortion:* As depicted in fig. 5, the voltage is found to have a positive while WFR is having slightly negative effect on the angular distortion. The probable explanation for the same may be that with the increase in voltage the overall energy of the arc increases and moreover the arc also spreads making the bead wider and spreading the heat over a wider area thereby causing more angular distortion. Whereas, with the increase of wire feed rate the heat has more of penetrating effect rather than the spreading effect.

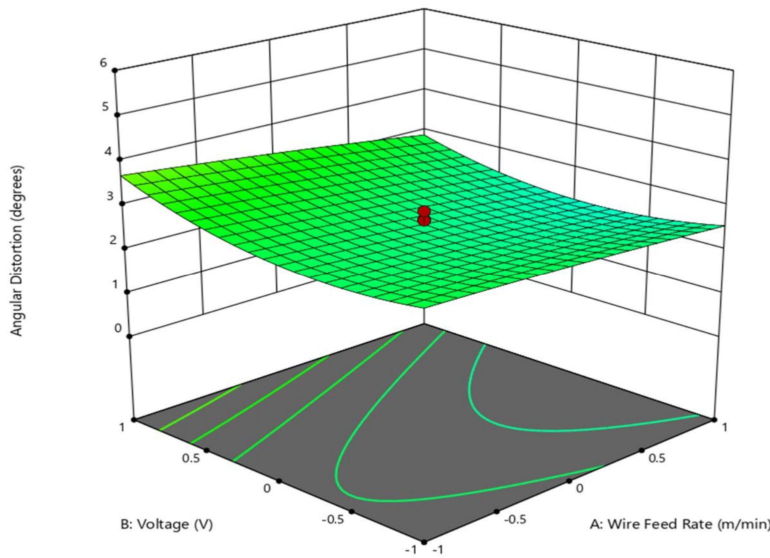

Fig 5 : Wire feed rate and voltage on angular distortion

2) *Torch Angle and Voltage on Angular Distortion:* From fig. 6, it can be inferred that maximum angular distortion is obtained at maximum voltage and minimum torch angle. The probable reason for this can be explained as at higher voltages the angular distortion is maximum as explained in previous section and at minimum torch angle, the angular distortion will be less as during back hand welding the heat remains into the weld for prolonged periods of time reducing the distortion. The minimum distortion is visible at maximum voltage and maximum torch angle where effect of torch angle seems to have outweighed the effect of voltage.

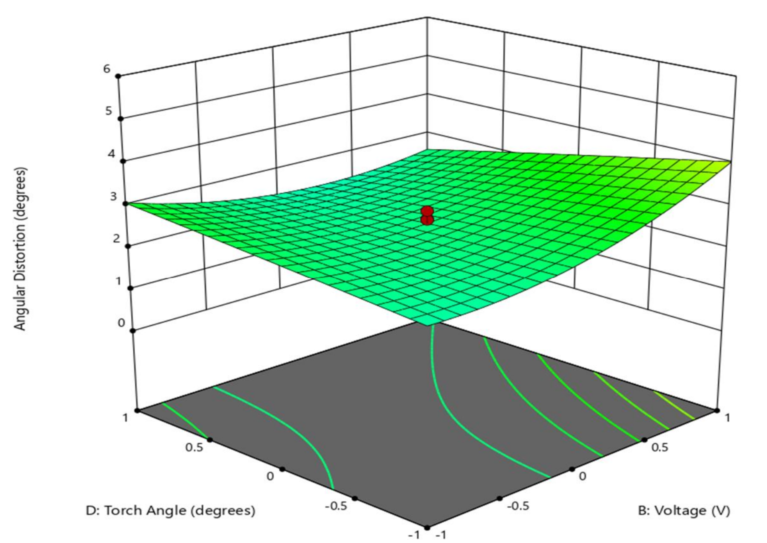

Fig 6 : Torch angle and voltage on angular distortion

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3) *NPD and Voltage on Angular Distortion:* Fig.-7 shows the interaction effects of voltage and NPD on angular distortion. As explained earlier, the angular distortion increased with the increase in voltage. At lower voltages, the angular distortion increased with the increase in NPD, the probable explanation for this could be that at lower voltages, with the increase in NPD, the reinforcement increases which increased the angular distortion. But at higher voltages with the increase in NPD the reinforcement reduces due to widening effect of voltage resulting in the overall reduction in angular distortion.

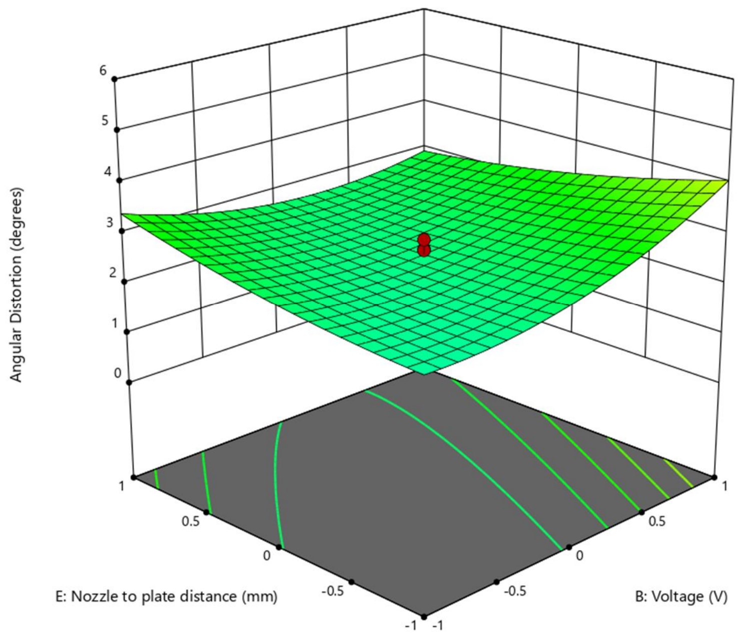

Fig 7 : NPD and Voltage on Angular distortion

IV. CONCLUSIONS

A. The maximum value of angular distortion is obtained at maximum voltage and minimum wire feed rate and minimum value is obtained at maximum wire feed rate and minimum voltage.

B. The maximum value of angular distortion is observed at maximum voltage and minimum torch angle, whereas the minimum value is obtained at minimum torch angle and minimum voltage.

C. The maximum value of angular distortion is obtained at maximum voltage and minimum NPD and the minimum value is obtained at minimum voltage and minimum NPD.

REFERENCES

[1] Upreti, M., Singh, A., Malik, A., Khanna, P., "Prediction of Angular distortion in TIG Welded Stainless Steel 202 Sheets by using Mathematical Modelling". International research journal of engineering and technology, Vol. 06 Issue. 04, pp. 4540-4545, April- 2019.

[2] Aggarwal, I., Faujdar, N., Das, A., Khanna, P., "Mathematical Modelling for Predicting Angular Distortion in TIG Welding of Stainless Steel 409l Butt Welds". International Journal of Research in Engineering and Technology, Vol.07 Issue. 06, pp. 92-97, June- 2018.

[3] Malik, D., Kumar, S., Saini, M., "Effect of process parameters on angular distortion of gas tungsten arc welded SS 302 and MS plate". International Journal of Research in Engineering and Technology, Vol.03 Issue. 08, pp. 18-24, august- 2014.

[4] Murugan, V.V, Gunaraj, V., "Effects of Process Parameters on Angular Distortion of Gas Metal Arc Welded Structural Steel Plates". American Welding Society and the Welding Research Council, pp. 165-171 , November-2005.

[5] Eskandari, M., Najafizadeh, A., Kermanpur, A., Karimi. M., "Potential application of nanocrystalline 301 austenitic stainless steel in lightweight vehicle structures". Elsevier science Ltd., pp. 3869-3872, April-2009.

[6] Hong, T., Nagumo, M., "Effect of surface roughness on early stages of pitting corrosion of Type 301 stainless steel", Elsevier science Ltd., pp. 1665-1672, 1997.

[7] Technical Note, "Stainless Steel- Austenitic- 201~201L~202~204", Aalco Metals Ltd. , Parkway House, Unit 6 Parkway Industrial Estate, Pacific Avenue, Wednesbury, West Midlands, WS10 7WP.

[8] Technical Note, "AWS Chemical Composition Requirements", Weldwire Company,103 Queens Drive, King of Prussia, PA 19406

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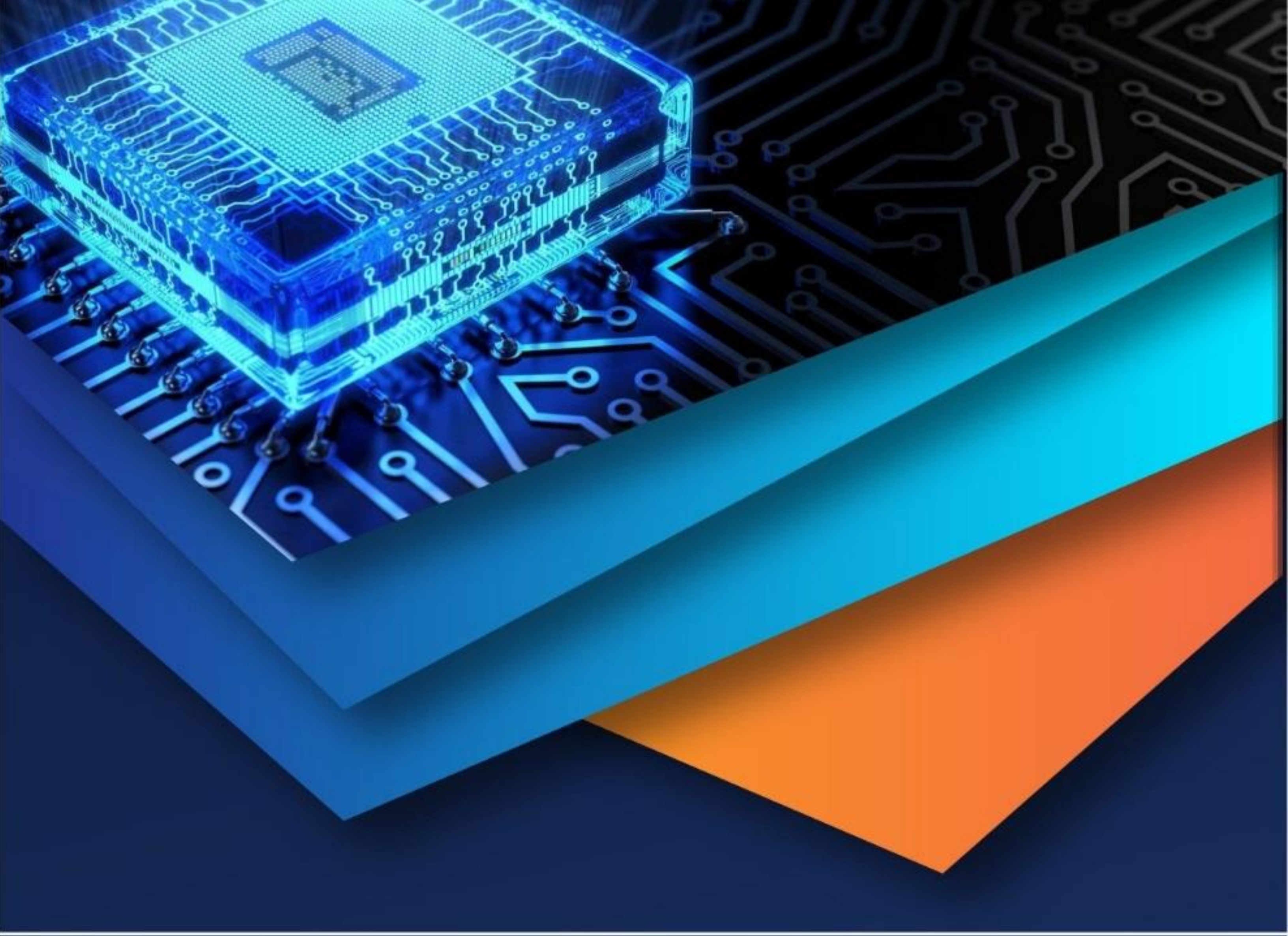

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